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LXIX. *Trigonometrical Height of Ingleborough above the Level of the Sea. Part II.* By JOHN NIXON, Esq.

[Continued from p. 261, and concluded.]

Of the Vertical Angles.

THE horizon sector was furnished with new arcs and verniers (the former in February 1827, and the latter in January 1832,) divided by the best engine in London, yet decidedly inferior in accuracy to the original graduations by Allan. Formerly the bubble of each cross level was adjusted to its mark when its arch stood parallel to a plumb line suspended near it, but latterly the adjustment has been effected in a superior manner. A block of wood $8\frac{1}{2}$ inches high, 6 long, and $2\frac{1}{2}$ thick, planed with its ends and sides perpendicular to its base, was mounted with a spirit-level, by which the base (by the process of reversing) could be set truly level. In this state, either arc when placed in exact contact with that end of the block in which recesses had been made for the protruding vernier, &c. would be vertical. Supposing the inclination of the arcs to be even 1° , an altitude of 2400 feet would be measured only 4 inches in excess, or in the proportion of the secant of the angle of inclination to radius.

In making bisections of pale, dim, or very distant objects, a dot* of about the same diameter as that of the vertical wire (spider's line), and adhering to one side of it a few minutes above the middle of its height, was successfully made use of up to 1832, when the filament mentioned in Lond. and Edinb. Phil. Mag., at page 166 of volume iv., was substituted. When the object was so near or dark that the dot or filament could not be seen distinctly against it, recourse was had to the horizontal wire, which was pointed in the first instance a little too high, and then gradually lowered (by moving a light weight placed within the stand of the sector in the direction of the object,) until the lower edge of the wire and the base of the signal, &c. seemed (from the inflection of light?) suddenly to commence running into each other. Zenith distances thus measured—as the second observation, with the telescope inverted, is made with the *opposite* edge of the wire and will be equally in defect with the preceding one—require in strictness a minute correc-

* The substitution of the dot for the horizontal wire arose from the impossibility of measuring the depression of the horizon of the sea with the latter. [It may be useful to some of our readers to refer in this place to the substitution of a dot for cross wires made by Mr. Gardner, in the trigonometrical operations for determining the difference of longitude between Paris and Greenwich, as stated by Capt. Kater in the Philosophical Transactions for 1828, p. 194—5, and considered by him to be a very important improvement in the theodolite.—EDIT.]

tion *additive* for the semidiameter of the wire. As the arcs are not fixed exactly parallel to each other, the dot does not make precisely half a revolution downwards on inverting the telescope, and therefore cannot come to the previous perpendicular distance from the axis of the cylindrical telescope by a quantity (too trivial, however, to be regarded,) equal to this distance multiplied by the versed sine of the deviation of parallelism of the arcs. It may be remarked also that when the cross wires are properly adjusted, the perpendicular one, from a defect in the stop, cannot be set quite parallel to either arc. This was first noticed on observing the dip of the sea, the horizontal wire being slightly inclined to the edge of the sea when either arc was vertical; but the deviation is not of a nature to vitiate the measurements. The reversing point* of neither of the great levels, but particularly of that marked G, proved so constant as heretofore; the seasoning which the levels had gradually acquired from repeated shocks in travelling, and by exposure to extremes of temperature, having been disturbed by dismounting them on commencing the survey and by frequent alteration of the adjustments, never in the course of any campaign, but during the intervening winters. As the fluctuation must have taken place chiefly on transporting the sector from one station to another rather than at the time of observation, the angles cannot have been materially affected in consequence. A register of the reversing points for each level is subjoined in a note†. Generally the sector

* That degree of the scale at which the middle of the bubble stands when the axis of the cylindrical tube of the telescope lies parallel to the horizon.

	† Dates.		Level G.		Level L.	No. of Observations.
1829.	August	20.	 74°6	....	71°2	... 2
		21.	 73·3	....	69·9	... 2
		22.	 75·2	....	72·5	... 3
		25.	 77·0	....	73·0	... 2
		28.	 77·9	....	73·2	... 1
	September	3.	 79·0	....	70·3	... 2
		14.	 78·8	....	71·5	... 1
		15.	 77·5	....	71·8	... 2
	October	16.	 74·2	....	70·5	... 2
		1.	 78·1	....	70·2	... 2
1830.	October	2.	 79·7	....	72·8	... 3
		4.	 79·3	....	71·7	... 2
		14.	 79·1	....	70·7	... 4
	November	21.	 77·7	....	71·3	... 2
		2.	 80·0	....	72·0	... 2
1832.	July	25.	 73·1	....	72·6	... 6
		27.	 72·2	....	68·3	... 3
	September	15.	 75·8	....	70·0	... 2
		18.	 76·4	....	69·5	... 1

(1° of the scale is about 2".)

The sector was supported either by solid masonry or bedded rock.

was supported by a firm pile of stones surmounted by a level flag, but in calm weather it was occasionally placed upon a large circular board, slightly concave at the upper surface, which was screwed firmly by its brass centre to the staff of the theodolite set up in the secure manner already described.

As the atmospherical refraction is generally fluctuating, the best method of obtaining its mean value correctly from the reciprocal observations and depressions, will be to class the observations at the several stations according to their dates rather than by the mean of the whole series. The following list, constructed on this plan from sixty-four observations made on eighteen different days in 1829, 1830 and 1832, exhibits a *mean* refraction of about $\frac{1}{17.3}$ of the contained arc. From this ratio the deviation of any day's observations (which is given in the last column,) is generally not only inconsiderable, but occurs in small arcs, where its effect on the differences of level becomes unimportant. With regard to the few striking exceptions, the one at Farleton Knot, marked K, was derived from a hasty measurement, on one arc only, of the elevation of Ingleborough as it was rapidly becoming obscured by mist. Those at Hest Wall originate, no doubt, in that horary variation of the refraction occurring in low situations on calm bright days, which rendered so uncertain the measurement of the height of the tide. All the observations at Clougha, marked C, with the exception of the three first made—those of Ingleborough,—concur in giving a refraction in excess, which may, perhaps, be accounted for by the wind, which was scarcely sensible at first, soon after blowing a strong gale* from the north-west, the quarter fronting the steep and lofty acclivity on which the pikes stand, and occasioning a condensation of that portion of air through which the rays from the several signals would finally pass. All the angles, but in particular the concluding one, that of the Breakwater pole, were uncertain to a few seconds, from the tremulous motion of the pile supporting the sector, which had been constructed, very improperly, partly of sods. The letters in the list refer to the dates given in the register of the observations.

* The strong breeze off the bay of Morecambe, which had blown at Hest Bank all the morning, subsided about the time the gale sprung up at Clougha.

Observed Refractions.

Stations.				Arc.	Refr.	Deviation from Mean.
Between Farleton Knot (L) and Hutton-Roof Moor (O)				1' 40"	-2".5	-8"
—	Warton Crag (F)	—	Hest Wall (U)	2 39	+11.7	+ 2.5
			do. (V)	2 39	15.3	+ 6
			do. (W)	2 39	15.3	+ 6
—	Warton Crag (G)	—	Hutton-Roof Moor (O)	4 16	16.0	+ 1.5
			do. (P)	4 16	14.8	0
—	Farleton Knot (K)	—	Warton Crag (F)	4 49	18.5	+ 2
—	BreakwaterPole(R)	—	Clougha Pike (A)	5 50	16.0	- 4
			do. (C)	5 50	32.8	+13
—	BreakwaterPole(R)	—	Hutton-Roof Moor (O)	7 26	27.5	+ 2
			do. (P)	7 26	31.0	+ 5.5
—	Warton Crag (F)	—	Clougha Pike (A)	7 42	18.7	- 8
			do. (C)	7 42	35.0	+ 8.5
—	Farleton Knot (K)	—	Hest Wall (U)	8 23	16.7	-12
			do. (V)	8 23	25.0	- 3.5
			do. (W)	8 23	26.3	- 2.5
—	Clougha Pike (C)	—	Hutton-Roof Moor (O)	9 42	38.3	+ 5
—	Ingleborough (T)	—	do. (P)	10 5	37.5	+ 3
			do. (Q)	10 5	41.0	+6.5
			Farleton Knot (J)	11 8	39.5	+1.5
—	Ingleborough (S)	—	do. (K)	11 8	30.3	-8
			do. (L)	11 8	37.5	-1
			do. (M)	11 8	36.5	-1.5
			do. (N)	11 8	36.5	-1.5
—	Clougha Pike (C)	—	do. (K)	11 9	35.4	-3.0
			do. (L)	11 9	37.2	-1.0
—	Ingleborough (S)	—	Clougha Pike (A)	13 22	44.5	-1.5
and (T)			do. (C)	13 22	+40.0	-1.6
Sum				3° 44' 37"	12' 58"	

Mean refraction of the whole $\left(\frac{12' 58''}{3^{\circ} 44' 37''}\right) = \frac{1}{17.3}$; say $\frac{1}{17.5}$.

Trigonometrical Differences of Level.

Explanation.—The angles of elevation (*El.*) and depression (*Dp.*) are given corrected for the cylindrical error of the instrument (= 20"). At every station the height of the eye above the point there selected for bisection is stated, and from these data the differences of level are computed with a *constant* refraction of $\frac{1}{17.5}$; but when any other point has been bisected, its height above (+) or below (—), the standard datum, is given within brackets. The distances prefixed to the angles are those from the sector to the point observed*. The devia-

* Call S the signal at the station, P the adjacent place of the sector, and O the distant signal observed; then add the log. cosine of the angle SPO

tion of the line of collimation from its mean value for each campaign is arranged in the last column; the bisections being marked D, F, or W, accordingly as they were made by the dot, filament, or wire.

At Clougha West Pike.

Dates. (A.) August 20, 1829, from 3 to 4 P.M. Sector on board. Eye $3\frac{1}{2}$ feet above the ground between the pikes.—(B.) October 18, 1830, at 3 P.M. Eye $4\frac{1}{2}$ feet.—(C.) September 18, 1832, from 1 to 3 P.M. Sector on a pile of stones and sods. Eye 3 feet.

Date Reference.	Station, &c. observed.	Distance.	Angle.		Diff. of Level.	Dev. Coll.
		Ft.			Ft.	
A {	Ingleborough	81522	0 36 44	El.	+1015.0	2.5 } W.
	do.	...	0 36 42	..	+1014.2	3.0 }
	do.	81520	0 36 40	..	+1012.8	1 }
C {	do.	...	0 36 39	..	+1012.2	0.5 } F.
	do. [tower top+22.3]	81343	0 37 32	..	+1009.0	3 }
A	Hest Breakwater Pole, top	35590	2 10 18	Dp.	-1318.4	1 } W.
C	do.	35587	2 9 36	..	-1312.5	9 }
C	Black Comb	158943	0 2 2	El.	+ 630.3	2 }
C	Farleton Knot	68036	0 29 28	Dp.	- 482.2	7.5 } F.
C	Hutton Roof Moor	59132	0 31 8	Dp.	- 458.7	1 }
C	Warton Crag	46933	1 3 29	Dp.	- 817.4	6 }
A	do.	46937	1 4 4	..	- 825.0	5.5 }
A {	Lancaster Church tower, top	24558	2 40 19	Dp.	-1129.8	0 } W.
	do.	...	2 40 24	..	-1130.4	1 }
B	do.	...	2 40 31	..	-1130.2	2.5 } D.

At Aqueduct Bank.

Dates. (D.) August 21, 1829, from $4\frac{1}{2}$ to $5\frac{1}{2}$ P.M. Eye 6 feet above the Lancaster Canal when full (?).—(E.) August 25, 1829, from 10 A.M. to noon. Eye, 6 feet. Sector on board both days.

			Ft.			Ft.	
D	Ingleborough }	{	91528	1 19 55	El.	+2310.0	1" } W.
	do. }	{	...	1 19 40	..	+2303.1	6.5 }
E {	do. }	{ [+1 ft.]*	...	1 19 47	..	+2306.5	2 }
	do. }	{	...	1 19 45	..	+2305.6	5 }
	do. }	{	...	1 19 38	..	+2302.5	2 }
D {	Clougha Pike }	{ [West	24822	2 56 9	El.	+1285.6	1 } W.
	do. }	{ Pike to	...	2 56 14	..	+1286.1	4 }
E {	do. }	{ +6.5]	...	2 56 18	..	+1286.7	4.5 }
	do. }	{	...	2 56 14	..	+1286.2	1 }

to the log. distance S P, and the sum *minus* radius will give a correction which, added to or subtracted from the distance S O accordingly as the angle S P O is obtuse or acute, will give that of P O.

* At Ingleborough the eye must be elevated 1 foot above the base of the signal to clear the view of the Aqueduct Bank.

[*Aqueduct Bank, continued.*]

D	{	Lancaster Church tower, top	Ft. 7412	1° 9' 14"	El.	+156.5	1"	} W.
		do.	...	1 9 20	...	+156.7	1	
E		do.	...	1 9 17	...	+156.6	4.5	
D		do. [N.W. pinnacle top +9.7]	...	1 13 43	...	+156.5	5.5	

At Aqueduct Bridge.

Date. (Y.) July 24, 1832, from noon to 1 P.M. Sector on south end of eastern battlement of bridge. Eye 13 feet above canal when full.

Y	{	Ingleborough	{	Tower top	Ft. 91365	1° 20' 16"	El.	+2300.9	4"	} F.
		do.	{	+22.3	...	1 20 18	...	+2301.5	1.5	
Y	{	Lancaster Church tower top*			7416	1 6 5	El.	+156.8	1	} W
		do.			...	1 6 3	...	+156.7	1.5	

At Hutton Roof Moor.

Dates. (O.) October 1, 1830, from 0½ to 3½ P.M.—(P.) October 2, 1830, from 10 A.M. to 3 P.M.—(Q.) September 13, 1832, from 3 to 3½ P.M. Sector each day on a pile of stones. Eye 4 feet above base of signal.

O	{	Breakwater Pole, top	Ft. 45299	1° 8' 33"	Dp.	— 856.1	1.5	} D.
		do.	...	1 8 42	...	— 858.1	1.5	
		do.	...	1 8 27	...	— 854.8	2.5	
P	{	do.	...	1 8 23	...	— 854.0	5.5	
		do.	...	1 8 42	...	— 858.1	1.5	} F.
P		Ingleborough	61513	1 17 46	El.	+1475.6	2.5	
Q	{	do.	61505	1 17 54	...	+1478.1	2.5	} F.
		do.	...	1 17 50	...	+1477.2	1.0	
P	{	do.	61311	1 19 17	...	+1475.2	14.5	} D.
		do.	...	1 19 18	...	+1475.5	5	
Q	{	do.	61304	1 19 18	...	+1475.9	5	} F.
		do.	...	...	...	...	...	
O		Warton Crag	26032	0 50 3	Dp.	— 360.6	3	} D.
P		do.	...	0 50 5	...	— 361.0	2.5	
O		Farleton Knot	10155	0 10 30	Dp.	— 24.8	0.5	} D.
O	{	Lancaster Church tower, top	57668	0 44 18	Dp.	— 668.8	3	
		do.	...	0 44 26	...	— 671.1	2	
P		do.	...	0 44 23	...	— 670.2	8	
O		Clougha Pikes, ground betw.	59145	0 22 18	El.	+ 461.7	3	} D.
P		Black Comb	140482	0 16 19	El.	+1088.8	3.5	

At Warton Crag.

Dates. (F.) August 21, 1829, from 11 A.M. to 1½ P.M.

According to Mr. Binns. the tower is 97 feet 6 inches high, and the (levelled) fall from its base to the canal when full, 59 feet 11 inches 6 tenths; together 157½ feet, or 1 foot more than by the above measurements. Taking the mean, the church tower top will be 157 feet above the canal, and 187 feet 4 inches (= 157+30.4) above the top of the Breakwater Pole.

Sector on board. Eye 4 feet above the ground at the signal.
—(G.) October 4, 1830, from $11\frac{1}{2}$ A.M. to $1\frac{1}{2}$ P.M. Sector on
the rock. Eye 5 feet.—(H.) October 15, 1830, from $1\frac{1}{2}$ to
 $2\frac{1}{2}$ P.M. Eye 5 feet.—(I.) July 25, 1832, from $6\frac{1}{2}$ to 7 P.M.
Sector on board. Eye $3\frac{3}{4}$ feet.

		Ft.	o	'	"		Ft.	"	
F	Hest Breakwater Pole, top	20836	1	24	2	Dp.	— 495·1	4	W.
	[—1·1]								
G	{ do.	20830	1	24	10	...	— 495·8	2	
H	{ do.	...	1	24	11	...	— 496·0	0·5	D.
I	{ do.	...	1	24	2	...	— 495·1	5·5	
I	{ do.	20834	1	23	47	...	— 494·7	5	F.
F	{ do. [-24·7]	20836	1	28	3	...	— 495·9	2·5	W.
	{ Ingleborough }	81847	1	12	4	El.	+ 1840·3	5·5	
G	{ do.	...	1	11	58	...	+ 1837·9	4·5	
	{ do. [Tower top,	...	1	11	51	...	+ 1835·2	4·5	D.
	{ do. [Tower top,	...	1	11	51	...	+ 1835·2	4·5	
I	{ do. [+22·3]	81837	1	12	8	...	+ 1841·3	2	F.
H	{ do.	...	1	12	8	...	+ 1841·3	3·5	
	{ do.	...	1	11	53	...	+ 1835·8	3	D.
F	{ do.	82046	1	11	0	...	+ 1839·5	1	
	{ do. [+1·0]	...	1	10	58	...	+ 1839·1	1·5	W.
	{ do.	...	1	10	59	...	+ 1839·1	3	
F	{ Lancaster Church tower, top	36097	0	32	14	Dp.	— 306·9	1	
	{ do.	...	0	32	13	...	— 306·9	3	
F	{ Hest Wall, top	22227	1	12	7	Dp.	— 451·9	3	W.
F	{ Clougha West Pike, top	46944	0	56	55	El.	+ 821·5	3	
	{ [+6·5]	...							
F	{ Farleton Knot	29346	0	36	53	El.	+ 337·1	3·5	
G	{ Hutton Roof Moor	26032	0	45	8	El.	+ 361·1	7	D.
E	{ Horizon of the Sea to the S.S.W. at 12 ^h 35 ^m P.M.* }	158520	0	23	5	Dp.	— 528·2	1·5	W.

At Ingleborough.

Dates. (S.) September 2, 1829, from $11\frac{1}{2}$ A.M. to 3 P.M.
Remarkably clear. Sector on signal pile. Eye 4 feet above
its base.—(T.) October 26, 1830, from 12^h 30^m to 2^h 30^m P.M.
Very clear, but intensely cold, with flakes of snow. Sector
as before. Eye $4\frac{1}{2}$ feet.

* It has been demonstrated at page 270, vol. v. that the included arc
will be equal to the observed dip *plus* twice the refraction; consequently
when the latter is $\frac{1}{17\cdot5}$ the apparent dip will be to the arc as 15·5 to 17·5
The angle (23' 5") increased in this proportion becomes 26' 4", for which
arc the refraction will be 1' 29"·5, and the curvature ($\frac{26' 4''}{2} =$) 13' 2".

With the distance corresponding to the arc (158520 feet,) and the tangent
of the dip, corrected for curvature and refraction (= 11' 32 $\frac{1}{2}$ ") the height
of the eye will be 532·2 feet and that of the Crag 528·2 feet.

		Ft.	°	'	"		Ft.
T	Ingleborough tower, top	188	5	23	42	El.	+ 22·3
S	{ Farleton Knot	67990	1	21	0	Dp.	-1500·8
	do.	...	1	20	57	...	-1499·8
T	{ Hutton Roof Moor	61513	1	27	2	...	-1473·2
	do.	...	1	27	8	...	-1475·0
S	{ Clougha Pikes, ground betw. ...	81530	0	49	0	...	-1017·6
	do.	...	0	49	0	...	-1017·6
T	{ do.	...	0	48	48	...	-1012·8
	do.	...	0	48	54	...	-1015·2
S	Lancaster Church tower, top	97198	1	23	3	...	-2145·2
S	Black Comb	201970	0	21	16*	...	- 383·8
T	{ do.	...	0	21	6	...	- 374·1
	do.	...	0	21	10	...	- 378·0

At Hest Breakwater Pole.

Date. (R.) October 21, 1830, from 10 to 10½ A.M. Sector on board. Eye (3½ feet above base,) 24½ feet below top of pole, which is 28 feet high.

			°	'	"		Ft.
R	{ Clougha West Pike, top	35594	2	7	26	El.	+1317·2
	[+5·0]	...	2	7	24	...	+1316·9
R	{ do. do.	45299	1	3	41	...	+ 858·1

At Farleton Knot.

Dates. (J.) Aug. 28, 1829, at 2 P.M. Sector on a rock. Eye 1 foot above base of signal; (a tremendous gale from the north.)—(K.) Aug. 29, 1829, from 10 A.M. to 2½ P.M. Sector on a pile of stones. Eye 1 foot.—(L.) Sept. 30, 1830, from 3 to 5 P.M. Sector as last.—(M.) Oct. 12, 1830, from 11 A.M. to 1 P.M. Sector as last.—(N.) Sept. 15, 1832, from 3½ to 4½ P.M. Sector on board. Eye 1 foot†.

		Ft.	°	'	"		Ft.
M	Hest Breakwater Pole, top	49983	1	1	2	Dp.	- 833·6
N	do.	49994	1	0	58	...	- 832·8
J	Ingleborough,	67990	1	10	55	El.	+1501·0
K	do.	67985	1	10	36	...	+1495·0
L	do.	67987	1	10	50	...	+1499·6
	do.	67986	1	10	50	...	+1499·6
N	{ do. ... ..	.....	1	10	45	...	+1498·0
	do. ... ..	.....	1	10	44	...	+1497·7
L	{ do.	67793	1	12	9	...	+1498·6
	do.	...	1	12	15	...	+1500·6
M	{ do. [Tower, top	...	1	12	13	...	+1500·0
	do. +22·3	...	1	12	12	...	+1500·0
N	{ do.	67792	1	12	8	...	+1498·4
	do.	...	1	12	17	...	+1501·4

* By Mudge, 22' 24"; (height of Eye 5½ feet.)

† The beds dip 30° to 40° from the edge of the cliff on which the signal stands.

		Ft.				Ft.	
K	{ Lancaster Church tower, top	63992	0	39	25	Dp.	— 646·2 2"
	do. .. ..	.....	0	39	26	..	— 646·6 4·5
L	do.	63991	0	39	26	..	— 646·6 8
K	Warton Crag	29344	0	41	40	Dp.	— 336·3 1·5
L	Hutton-Roof Moor	10145	0	7	4	El.	+ 24·0 2·5
K	Hest Wall, top	51140	0	57	1	Dp.	— 791·7 2
	Clougha West						
K	{ Pike, top } [+ 6·5]	68037	0	19	40	El.	+ 481·6 1
	do. .. ..	.....	0	19	34	..	+ 479·5 3
L	do. [+ 5·0 ]	.....	0	19	36	..	+ 481·5 2·5
M	{ Black Comb	134460	0	18	30	El.	+ 1106·5 6·5
	do. .. ..	.....	0	18	28	..	+ 1105·3 1·5

At Hest Wall.

Dates. (U.) Aug. 24, 1829, at 3 P.M.—(V.) Sept. 14, 1829, at 12½ P.M.—(W.) Sept. 16, 1829, at 3 P.M.—(X.) Oct. 20, 1830, at 11 A.M. Eye 0½ foot above Wall top.

U	Warton Crag	22222	1	8	10	El.	+ 451·7 1	W.
V	do. .. ..	.....	1	8	17	..	+ 452·5 6·5	
W	do. .. ..	.....	1	8	17	..	+ 452·5 0·5	
X	{ Hutton-Roof Moor	46052	0	56	27	El.	+ 814·8 0	D.
	do. .. ..	.....	0	56	27	..	+ 814·8 0·5	
U	Farleton Knot	51149	0	49	5	El.	+ 786·0 1·5	W.
V	do. .. ..	.....	0	49	22	..	+ 790·4 1	
W	do. .. ..	.....	0	49	24	..	+ 790·9 1·5	D.
	Aug. 24, 1829, Breakwater Pole, top	2339·3	1	4	58	Dp.		
	25, 1829. do. do. ....	.....	1	4	58	..	— 43·2	
	July 25, 1832. do. do. ....	.....	1	5	4	..		
	Aug. 24, 1829. do. base .. ..	.....	1	45	46	Dp.		
	do. do. do. ....	.....	1	46	13	..		
	Aug. 25, 1829. do. do. ....	.....	1	46	0	..		
	do. do. do. ....	.....	1	46	28	..		
	Oct. 14, 1830. do. do. ....	.....	1	46	23	..		
	do. do. do. ....	.....	1	45	46	..		
	Oct. 20, 1830. do. do. ....	.....	1	46	28	..		
	do. do. do. ....	.....	1	46	6	..		

In 1829 Hest Bridge top measured 17 feet above the Lancaster Canal, and 4·2 feet above Hest Wall; whence the Wall is 12·8 above the canal. The Pole top being 43·2 below Hest Wall will be 30·4 lower than the canal.

The following table exhibits for every intermediate station each day's observed difference of level between Ingleborough and the Breakwater Pole top, derived as well directly as through the medium of Lancaster church tower and Hest Wall, together with their respective heights above the Pole. When an observation of the hill was not accompanied on the

same day by one either of the pole or church, the deficiency was supplied from the mean of all those registered.

			By B. Pole	By L. Church.	By Hest Wall.
At Clougha Pike	{ 2 Obs. ... A		2330·0	2332·1	
	{ 3 — C		2323·6	2328·7	
At Aqueduct Bank	{ 1 — D		2340·6	2341·0	
	{ 4 — E		2335·0	2335·4	
At Aqueduct Bridge	{ 2 — Y		2331·8	2332·0	
	{ 3 — F		2334·7	2333·5	2334·3
At Warton Crag	{ 4 — G		2333·0	2331·4	2332·8
	{ 1 — H		2330·9	2330·1	2330·9
	{ 2 — I		2336·0	2335·6	2336·4
At Hutton-Roof Moor	{ 3 — P		2331·0	2333·0	
	{ 3 — Q		2333·5	2334·5	
	{ 1 — J		2334·3	2335·0	2335·9
	{ 0½ — K		2328·2	2328·9	2329·9
At Farleton Knot	{ 3 — L		2332·8	2333·6	2334·6
	{ 3 — M		2333·0	2333·4	2334·4
	{ 4 — N		2332·0	2333·1	2334·1
Mean of each day's obs. . . .			2332·9	2333·4	2333·9
Do. of all the obs. . . .			2332·4	2333·2	2334·1
					Means. 2333·5 2333·0

The altitude may be found exclusively from the depressions, at Ingleborough, of Farleton Knot, Hutton-Roof Moor, Clougha Pike, and Lancaster church tower, together with the elevations of the three stations above the pole, as measured at the Breakwater and Hest Wall, and that of the church tower as determined by levelling, &c.

By obs. of Farleton Knot 2332·5 }
 Hutton-Roof Moor 2332·1 } Mean, 2332·5 feet.
 Clougha Pike 2332·8 }
 Lancaster Church . 2332·6 }

Giving the due weight to the different methods, the height of Ingleborough above the top of Hest Breakwater Pole may be considered as 2333 feet.

Height of Hest Breakwater Pole above the Tides.

Having filled up by interpolation the eight blanks in the given list of the observed heights of the Pole top above high water, from July 7 to August 7, 1832, the mean will be 26 ft. 8 in. By Holden's Tables, which are founded on five years' observations at Liverpool, and are considered very exact, the predicted mean height of the (day) tides within the same period is 14 ft. 10 in. above the old dock sill, which is 8 ft. 9 in. above the average low-water mark of spring tides, and 1 ft. 9 in. above that of neaps. To render Holden's heights

comparable with those of our list they must be subtracted from 41 ft. 6 in. (= 14 ft. 10 in. + 26 ft. 8 in.), when each day's difference will stand as follows:

1832.

July 7th .. + 5 inches.	July 18th .. - 2 inches.	July 29th .. + 3 inches)
(8 .. + 10	19 .. - 7	30 .. - 8
9 .. + 10	(20 .. - 9)	31 .. - 11
10 .. + 7	21 .. - 12	Aug. 1 .. - 14
11 .. + 12	(22 .. - 2)	2 .. - 12
12 .. + 5	23 .. + 1	(3 .. - 9)
13 .. + 6	24 .. - 1	4 .. - 8
14 .. + 1	25 .. + 3	(5 .. 0)
15 .. + 3	26 .. + 3	6 .. + 2
16 .. + 7	27 .. + 1	7 .. - 5
17 .. + 2	(28 .. - 2)	

At *high water* the difference of level between spring and neap tides may be considered the same at both places.

Call PO the *observed* height of the pole top above the sea in a given state of the tide, and PH its corresponding mean value for 1832--3, derived from Holden's Tables. 1. At *spring tides** PH will be 23 ft. at mean high water, and 50·3 at mean low water. July 28th, 1832, PO was 22·6, and the height of the tide (at Heysham) 29·3; whence PO would become 51·3 at mean low water, spring tides. 2. At *neap tides** PH is 29·6 at mean high water, and 43·3 at mean low water. July 20th, 1832, PO was 28·10, and the height of the tide at Heysham 18·3; whence PO may be stated at 46·5 at mean low water neap tides. 3. At mean high water PH will be

$$\left(\frac{23 + 29\cdot6}{2}\right) = 26\cdot3, \text{ or } 26\cdot2 \text{ by the mean of every day}$$

tide within the two years. 4. At mean low water PH is $\left(\frac{50\cdot3 + 43\cdot6}{2}\right) = 46\cdot10$, and PO = 48·10 $\left(= \frac{51\cdot3 + 46\cdot5}{2}\right)$.

5. At the mean level of the sea PH will be 36·6; the measurements at Heysham give PO = 38 at neaps and 37 at springs, mean 37·6 †.

January 29th, 1823. Mr. Binns levelled from the canal at Hest to the shore 400 yards to the northward, and thence 1923 yards on the sands to the lowest (?) part of the channel of the Keer‡, and found the fall 76·9 (or 46·5 below the pole).

* Spring tides were considered the two highest, and neap tides the two lowest tides within a lunation.

† At Liverpool the difference of level between springs and neaps is much the same at high and low water, or about 7 ft.; but at Heysham the difference at low water cannot exceed 5 ft. It may therefore be doubted whether the lake subsides at spring tides to the level of the open sea.

‡ "A small channel near the land at Hest was lower by 3 inches than the point levelled to."

As the tide measured 25·9 in height, it would have been at high water 20·8 below the pole top, or about the level of the highest tide in my list; at least a 30-ft. tide. It may therefore be concluded, as indeed Mr. Binns intimates, that the point levelled to was some feet above low water. In proof, he states that the canal, when full, is $76\frac{1}{2}$ ft. above the sill of Glasson dock gates, (consequently about the level of the channel of the Keer,) from which the tide sometimes ebbs out three to five feet.

The height of Ingleborough may now be stated as 2370·5 ft. above the mean level of the Irish Sea, and as

2384·5 ft. above *mean* low water spring tides *;

2379·5 — — — neap —

2356·0 — *mean* high water spring tides;

2362·5 — — — neap —.

The height of each sector station above mean low water spring tides, obtained on the same plan as that of Ingleborough, is given in the following list.

By obs. at	Clougha.	Warton Crag.	Farleton Knot.	Hutton-Roof Moor.
Breakwater	1368·3			909·4
Hest Wall .. ..	.....	546·7	883·6	909·3
Warton Crag	1367·5	546·1	883·1	907·1
Farleton Knot	1365·8	548·5	884·9	908·9
Hutton-Roof Moor .	1369·8	547·3	883·3	908·1
Clougha Pike	1369·3†	544·3	884·0	907·5
Ingleborough	1368·1		883·7	909·8
Aqueduct Bank	1368·1			
Mean	1368·1	546·6	883·9	908·6‡

Having measured from three intermediate stations in Wharfedale, the difference of level between Ingleborough and Roseberry Topping, the resulting altitude of the latter exceeded considerably its elevation above the German Ocean at Redcar, as measured by Col. Mudge from the intermediate station at Burleigh Moor. It is however evident that either the data for determining its distance from Burleigh Moor are incorrectly stated, or that an error of — 1802 feet (= — 33 ft. in the altitude,) has been committed in the calculation.

The height of Black Comb measures 1989·8 from Farleton Knot, 1997·4 from Hutton-Roof Moor, 1998·4 from Clougha, and 2005·7 from Ingleborough; mean 1997·8. Col. Mudge states it at 1919 feet.

Chapel Allerton, near Leeds,
Feb. 5th, 1833.

JOHN NIXON.

* Hitherto called 2374·5 ft. Mudge makes it 2361 ft.

† Rejecting the obs. marked (C).

‡ Summit of moor, 911·6 ft.